Ar^{40}/Ar^{39} geochronology of the Hualapai Limestone and Bouse Formation and implications for the age of the lower Colorado River

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The Hualapai Limestone in the Lake Mead area is the youngest member of the upper Miocene Muddy Creek Formation (e.g., Blair and Armstrong, 1979; Bohannon, 1984) and is well exposed in Grand Wash trough where the Colorado River exits the lower Grand Canyon. Studies by Ivo Lucchitta of facies relationships and sediment dispersal patterns in the Muddy Creek Formation in Grand Wash trough reveal no evidence of voluminous sediment delivery from an ancestral Colorado River, which indicates that the Colorado River did not enter the Lake Mead area until later (Lucchitta, 1972, 1979, 1987, 1989, 1990). This is consistent with Sr isotopic dissimilarity of the Hualapai Limestone and Colorado River water (Spencer and Patchett, 1997). An 80-cm-thick, friable tuff bed within the Hualapai Limestone, containing remarkably fresh biotite and glass shards, yielded a $^{40}Ar/^{39}Ar$ plateau age from biotite of 5.97 ± 0.07 Ma (2σ error; 95.6% of total gas; sample location: 35°58.49'N., 114°24.79'W., roadcut at elev. 2080 ft.; Spencer et al., 1998). The lower Colorado River did not, therefore, arrive in the Lake Mead area until after 6 Ma.

The Pliocene Bouse Formation was deposited in the lower Colorado River trough south of the Hualapai Limestone and all Bouse exposures are confined to a string of 4 basins along the modern Colorado River. Deposition occurred after eruption of a tuff interbedded with underlying fanglomerate that has been dated at 9.2±0.3 Ma (K-Ar sanidine; Buising and Beratan, 1993). Basal Bouse strata in all four basins consists of marl, locally interbedded silt, sand, and gravel, and bedrock-coating tufa. In the basin interior facies of the southern basin (Parker-Blythe-Cibola area), the marly sediments are overlain by a few tens to perhaps a hundred meters of siltstone with less common sandstone (Buising, 1990). Grain size generally increases upward into cross-bedded sands that are in turn overlain by Colorado River gravels. Modal mineralogy analysis by Buising (1988, 1990) indicates that Bouse sands and sands associated with Colorado River gravels are mineralogically indistinguishable, but that both differ from underlying, more quartz-poor sands associated with locally derived fanglomerate. Mixed angular- and rounded-clast conglomerate in the top few meters of the fanglomerate underlying the Bouse Formation contains a gray sand matrix that "contains extremely sparse material of probably Colorado Plateau derivation" (Buising, 1990). Deposition of the Bouse Formation was thus accompanied by delivery of quartz-rich sand and silt from the Colorado River.

A tuff bed in the Bouse Formation, located in the Buzzards Peak area of the Chocolate Mountains in California and at one of the southernmost Bouse exposures, yielded a K-Ar date from glass of 5.47±0.20 Ma (Damon and others, 1978; Shafiqullah et al., 1980). Glass is not known to be a reliable K-Ar dating medium, so the tuff was resampled and dated by the $^{40}Ar/^{39}Ar$ method using incremental heating of bulk samples. Both plagioclase and glass separates were derived from the tuff sample, and no other datable materials were found. The plagioclase yielded an incremental-heating age spectrum with disturbed low-temperature steps that possibly resulted from a small amount of glass contamination or alteration of the plagioclase. Higher temperature heating steps yielded a plateau age of 17.5±0.5 Ma from ~60% of the total released argon. This age is interpreted as the likely product of xenocrystic plagioclase and the plateau age is considered to be unrelated to the age of the tuff. Two samples of glass were analyzed, and both yielded argon-release spectra with slightly increasing indicated ages for progressively higher temperatures. Failure to obtain flat argon-release spectra is possibly due to argon loss associated with hydration or alteration of the glass. The most reliable age information is probably from moderate-temperature heating steps which were below the temperatures at which argon was likely derived from contaminating xenocrystic plagioclase as indicated by a dramatic drop in K/Ca accompanied by a rise in age. These moderate-temperature heating steps yielded ages of 4.76±0.25 Ma (heating step at 950° that yielded 17.6% of total ^{39}Ar) and 5.01±0.09 Ma (heating step at 975° C that yielded 20.5% of ^{39}Ar). If the climbing age spectra of the glass samples are interpreted as due to argon loss (our preferred interpretation), then 5.01±0.09 Ma age, derived from the second glass analysis with smaller heating steps (75° instead of 100° C), is considered the best estimate for the minimum age of eruption of the tuff. Total gas ages for the two glass samples, 4.56 and 4.8 Ma, suggest that the older 5.47±0.20 Ma date obtained by Damon and others (1978) resulted from minor contamination of their glass sample by xenocrystic plagioclase.

It thus appears that initial arrival of Colorado River water to the lower Colorado River trough is constrained as follows: (1) The Colorado River did not enter the Lake Mead area until after deposition of the Hualapai Limestone and the 5.97 ± 0.07 Ma tuff within it. (2) Colorado River water was flowing into the lower Colorado River trough and was delivering quartz-rich sediments to the Bouse Formation when a tuff bed was deposited in the Chocolate Mountains. This tuff bed yielded a ^{40}Ar/^{39}Ar single-step date of 5.01±0.09 Ma that is interpreted as a minimum age for tuff deposition. (3) Delivery of voluminous clastic sediments from the Colorado River to the Salton trough began at 4-5 Ma (Johnson et al., 1983; Kerr and Kidwell, 1991). We conclude that the Colorado River began flowing through the Lake Mead area and into the lower Colorado River trough between 4 and 6 Ma (constraints 1 and 3), and probably between 5 and 6 Ma (constraints 1 and 2).

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